

What is claimed is:

1 1. A method of forming capacitors having geometric
2 deep trenches, comprising:
3 providing a substrate;
4 forming a pad structure on the substrate;
5 forming a first hard mask layer on the substrate;
6 forming a patterned second hard mask layer on the first
7 hard mask layer to expose a first opening;
8 forming a spacer layer in the first opening on the
9 first hard mask layer to expose a second opening;
10 forming a third hard mask layer to fill the second
11 opening;
12 removing the spacer layer to expose the first hard mask
13 layer;
14 etching the first hard mask, with the second hard mask
15 layer and the third hard mask layer acting as
16 masks, to form a third opening with a salient of
17 the first hard mask layer therein;
18 removing the second hard mask layer and the third hard
19 mask layer; and
20 etching the first hard mask, the salient of the first
21 hard mask layer, the pad structure, and the
22 substrate to form a geometric deep trench in the
23 substrate.

1 2. The method as claimed in claim 1, after forming a
2 third hard mask layer to fill the second opening, further
3 comprising subjecting the third hard mask layer to a

4 flattening process to remove the third hard mask layer
5 beyond the second opening.

1 3. The method as claimed in claim 1, wherein the
2 flattening process is chemical mechanical polishing.

1 4. The method as claimed in claim 1, wherein the
2 first hard mask layer is BPSG, AsSG, PSG, or BSG.

1 5. The method as claimed in claim 1, wherein the
2 second hard mask layer is polysilicon or doped polysilicon.

1 6. The method as claimed in claim 1, wherein the
2 third hard mask layer and the third hard mask layer are the
3 same material.

1 7. The method as claimed in claim 1, wherein the spacer
2 layer is dielectric material.

1 8. The method as claimed in claim 1, further
2 comprising conformally forming the spacer layer with LPCVD,
3 PECVD, HDPCVD, APCVD, or SACVD.

1 9. The method as claimed in claim 1, wherein the pad
2 structure comprises a pad oxide layer and a pad nitride
3 layer, and the steps of forming the pad structure comprise:
4 forming a pad oxide layer on the substrate; and
5 forming a pad nitride layer on the pad oxide layer.

1 10. The method as claimed in claim 1, wherein the
2 process of forming the geometric deep trench in the
3 substrate comprises:

4 etching the first hard mask layer, the salient of the
5 first hard mask layer, and the substrate to remove
6 the salient of the first hard mask layer
7 completely to form a doughnut-shaped hollow in the
8 substrate; and

9 etching the doughnut-shaped hollow of the substrate and
10 the pad structure to form the geometric deep
11 trench in the substrate.

1 11. The method as claimed in claim 1, wherein the
2 first hard mask layer is etched to form a residual first
3 hard mask layer simultaneously, when the salient of the
4 first hard mask layer is removed completely by etching.

1 12. The method as claimed in claim 1, wherein the
2 width of the second opening is in inverse ratio to the
3 thickness of the spacer layer

1 13. The method as claimed in claim 12, wherein the
2 width of the salient of the first hard mask layer is in
3 direct ratio to that of the second opening.

1 14. The method as claimed in claim 1, further
2 comprising, after forming a geometric deep trench in the
3 substrate, steps of:

4 forming a buried plate in parts of the substrate of the
5 geometric deep trench; and

6 forming a collar insulating layer and at least one
7 conductive layer in the geometric deep trench.

1 15. A method of forming capacitors having geometric
2 deep trenches, comprising:

3 providing a substrate;
4 forming a pad structure on the substrate, comprising a
5 pad oxide layer and a nitride layer formed on the
6 substrate sequentially;
7 forming a first hard mask layer on the substrate;
8 forming a patterned second hard mask layer on the first
9 hard mask layer to expose a first opening;
10 forming a spacer layer in the first opening on the
11 first hard mask layer to expose a second opening;
12 forming a third hard mask layer to fill the second
13 opening;
14 performing a flattening process to remove the third
15 hard mask layer beyond the second opening.
16 removing the spacer layer to expose to the first hard
17 mask layer;
18 etching the first hard mask, with the second hard mask
19 layer and the third hard mask layer acting as
20 masks, to form a third opening with a salient of
21 the first hard mask layer therein;
22 removing the second hard mask layer and the third hard
23 mask layer;
24 etching the first hard mask layer, the salient of the
25 first hard mask layer, and the substrate to remove
26 the salient of the first hard mask layer
27 completely to form a doughnut-shaped hollow in the
28 substrate; and
29 etching the doughnut-shaped hollow of the substrate and
30 the pad structure to form the geometric deep
31 trench in the substrate

1 16. The method as claimed in claim 15, wherein the
2 flattening process is chemical mechanical polishing.

1 17. The method as claimed in claim 15, wherein
2 formation of the pad oxide layer of the pad structure uses
3 thermal oxidation.

1 18. The method as claimed in claim 15, wherein the
2 first hard mask layer is BPSG, AsSG, PSG, or BSG.

1 19. The method as claimed in claim 15, wherein the
2 second hard mask layer is polysilicon or doped polysilicon.

1 20. The method as claimed in claim 15, wherein the
2 third hard mask layer and the third hard mask layer are the
3 same material.

1 21. The method as claimed in claim 15, wherein the
2 spacer layer is dielectric material.

1 22. The method as claimed in claim 15, wherein
2 conformal formation of the spacer layer uses LPCVD, PECVD,
3 HDPCVD, APCVD, or SACVD.

1 23. The method as claimed in claim 15, wherein the
2 first hard mask layer is etched to form a residual first
3 hard mask layer simultaneously, when the salient of the
4 first hard mask layer is removed completely by etching.

1 24. The method as claimed in claim 15, further
2 comprising, after forming a geometric deep trench in the
3 substrate:

Header. : 91255

Our ref: 0548-9628US/final/Phoelip/Kevin revised

4 forming a buried plate in parts of the substrate of the
5 geometric deep trench; and

6 forming a collar insulating layer and at least one
7 conductive layer in the geometric deep trench.

8